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Some Recognitions Obtained by Software EVAL-7

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Abstract: The relaxed strains determined by computer simulation of hole-drilling process were evaluated by different methods included in software EVAL-7 (SINT Technology). The relative errors of residual stresses were compared on conditions of elastic stress field and on condition of small plasticity in the area of strain gauge rosette. Applicability of the rule "principal stress smaller than 0.5 of the yield stress" was discussed.

Keywords: Residual Stresses; Residual Stress Measurement; Hole-Drilling Method.

1 Introduction

Residual stresses are the inevitable consequence of thermal-mechanical processing of metals. Among of all methods for their experimental investigation is the hole-drilling procedure most frequently used. To this purpose the automatic system MTS300-RESTAN (SINT Technology) and software EVAL-7 are providing valuable support.

The main functions of the EVAL-7 are to fit measured strain values versus the hole depth and calculate residual stresses.

In the EVAL-7 exist 9 methods for evaluation of residual stresses for the hole-drilling method: ASTM E837-08-UN (for uniform residual stress field through the thickness), ASTM E837-08-EXT-UN (extended uniform, optimized calibration coefficients), ASTM E837-13-UN, ASTM E837-13-EXT-UN, ASTM E837-13-N-UN (non-uniform), ASTM E837-13-EXT-N-UN (extended non-uniform), Integral method (variable calculation steps). Schwarz-Kockelmann method (variable calculation steps), HDM method (non-uniform residual stress curve with variable calculation steps considering the real strain gage dimension and eccentricity - proposed by the University of Pisa).

The aim of this contribution is:

- compare the relative errors of residual stresses determined by several methods on condition of elastic stress field in the area of strain gage rosette,
- the same – but on condition of small plasticity in the area of strain gage rosette; the criterion of ASTM E837 is fulfilled in this case,
- assess applicability of the rule "maximum principal stress smaller than 0.5 (0.6) of the yield stress".

The computer simulation method was preferred over the real model investigation.

2 Computer Simulation using FEM

Finite element model was created by discretization of geometry model. For discretization were used linear elements SOLID92. Future hole was meshed by mapped algorithm with uniform distribution of 20 elements along depth of hole. Uniform distribution was necessary for creating 10 layers with same thickness to simulate drilling on the 10 steps. Eleven bilinear material models were created for eleven different temperatures. Material was created as temperature-dependent to control stiffness of layers. To each layer of elements were assigned one temperature-dependent material model. After drilling each layer of elements, the elements in corresponding layer become much more elastic – negligible. Steel plate were modelled as one eighth to use symmetry. Deformation boundary conditions were modelled using three planes of symmetry. Load of geometry were modelled using two pressures (S1 and S2). By changing those pressures could be simulated uniaxial, biaxial and shear stress.

After solving the simulation post processing was performed to obtain resulting strains. Strains were obtained from areas where imaginary strain gauge rosette was placed. The main results from simulation were strains from each strain gauge (total of three) after removing individual layers of elements.

3 Results

From equivalent stresses evaluated in different depths the statistical characteristics were determined (see Tab. 1 and Tab. 2): $\overline{\sigma}_{eq}$ [MPa] mean equivalent stress, c_v [-] coefficient of variation (the ratio of standard deviation to mean), δ [%] relative error of mean equivalent stress. These data relates to condition a) of elastic state state of stress, b) partial plastification of the rosette area (figures in brackets).

Tab. 1: Uniaxial tension.

	13-N-UN	13-EXT-N-UN	INT	KOCK	HDM
$\overline{\sigma}_{eq}$ [MPa]	593 (368)	544 (335)	496 (307)	507 (311)	507 (313)
c_v [-]	0.06 (0.08)	0.06 (0.08)	0.03 (0.03)	0.08 (0.08)	0.01 (0.02)
δ [%]	18.6 (22.5)	8.7 (11.7)	0.7 (2.2)	1.4 (3.8)	1.3 (4.4)

Tab. 2: Plane shear.

	13-N-UN	13-EXT-N-UN	INT	KOCK	HDM
$\overline{\sigma}_{eq}$ [MPa]	530 (568)	474 (510)	431 (463)	451 (481)	441 (474)
c_v [-]	0.07 (0.05)	0.05 (0.04)	0.02 (0.05)	0.05 (0.10)	0.01 (0.05)
δ [%]	22.4 (31.3)	9.5 (17.7)	0.6 (6.9)	4.1 (11.2)	1.8 (9.4)

4 Analysis of Results

From the results in Tab. 1 and Tab. 2 is possible to examine:

- the influence of rosette dimension used in ASTM and in previous calculations,
- the influence of small plasticity in the region of strain gage grid on relative error of evaluated residual stresses,
- context of stress biaxiality and rule “maximum principal stress smaller than 0.5 of yield stress”.

5 Conclusion

- Software EVAL-7 covers a number of methods for evaluation of residual stresses on the basis of hole-drilling method and strain gauge measurement.
- From the analysis performed should be deduced that for rosette 1.5 RY61S is not most suitable using the calibration coefficients from ASTM E837. Elaboration of calibration coefficients by SINT Technology for series of rosettes on the market is a benefit for application of hole-drilling method.
- Limit value of residual stress evaluated on the basis of elastic solution depends on the stress biaxiality.

References

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